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74600
ATTENUATOR

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ATTENUATOR

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THESE direct-reading push button attenuators provide the high accuracy and precision required for measurements extending into the V.H.F. range, which are of particular importance in modern telecommunication systems. At these frequencies the effects of mutual impedances and unwanted reactances have great significance and can easily result in a marked deterioration in performance.

Fully patented, the constructional features of the attenuators include an ingenious switching circuit, special high-stability resistors, effective internal screening, and a precise assembly of all components. The result is a precision attenuator having a performance which is without precedent at frequencies up to 65 or 100 Mc/s (according to the model).

Details are given below of the various models, which are now in quantity production. They are available with a characteristic impedance of either 50 ohms or 75 ohms, with attenuation steps of 0·1 db, 1 db, and 10 db, and with various input and output connectors. Symmetrical T or π pads are used throughout with the exception of the attenuators having 0·1 db steps, where L pads are used. As can be seen from the typical impedance figures, the use of unsymmetrical pads for the low values of attenuation has no practical disadvantage.

The attenuators are designed for mounting on the customer's own panel.

Model	Range	Characteristic Impedance
74600-A	0 to 9 db in 1 db steps	75 ohms
74600-B	0 to 90 db in 10 db steps	75 ohms
74600-C	0 to 0·9 db in 0·1 db steps	75 ohms
74600-E	0 to 9 db in 1 db steps	50 ohms
74600-F	0 to 90 db in 10 db steps	50 ohms

In all the above models, the input and output connections are made via Belling-Lee type L604S sockets and type L734 plugs. These are the preferred types and delivery can generally be made from stock. Additional models fitted with Post Office, or American type BNC, connectors are available as follows:

Model	Range	Characteristic Impedance	Connectors
74600-G	0 to 9 db in 1 db steps	75 ohms	P.O. No. 1
74600-H	0 to 90 db in 10 db steps	75 ohms	„
74600-T	0 to 0·9 db in 0·1 db steps	75 ohms	„
74600-L	0 to 9 db in 1 db steps	50 ohms	„
74600-M	0 to 90 db in 10 db steps	50 ohms	„
74600-Q	0 to 9 db in 1 db steps	75 ohms	American BNC type
74600-R	0 to 90 db in 10 db steps	75 ohms	„
74600-S	0 to 0·9 db in 0·1 db steps	75 ohms	„
74600-J	0 to 9 db in 1 db steps	50 ohms	„
74600-K	0 to 90 db in 10 db steps	50 ohms	„

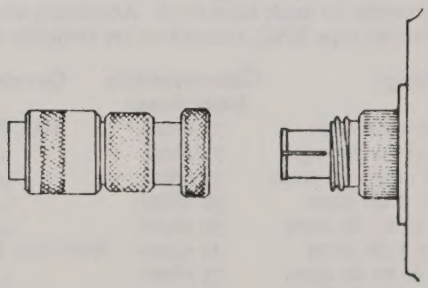
MODELS 74600-V & 74600-W

These two models are fitted with S.T.C. 58-LTA-5 Plugs at input and output. The corresponding 219-LTA-8 cord members are usually available and are therefore not normally supplied with the Attenuators.

Apart from the input and output connections, the performance and characteristics of these models are respectively identical to those of Models 74600-A and 74600-B, i.e. 74600-V corresponds to 74600-A, and 74600-W corresponds to 74600-B.

The dimensions for the Table on page 8a are:-

Grp	Termination	Type of Case	Dimension x	Dimension y	Dimension z
V	S.T.C. 58-LTA-5 Plug & S.T.C. 219-LTA-8 Socket.	I	0.870 in. 22,1 mm	1.070 in. 27,2 mm	7.815 in. 199 mm
W	S.T.C. 58-LTA-5 Plug & S.T.C. 219-LTA-8 Socket	II	0.330 in. 8,4 mm	1.070 in. 27,2 mm	8.275 in. 210 mm



Performance

INSERTION LOSS

When used between impedances equal to the characteristic impedance of the attenuator, the insertion loss relative to that at the 0 db setting will not be in error by more than the following values.

D.C. Performance

0 to 0·9 Attenuators (74600-C, S, T):	±0·002 db per step.
0 to 9 db Attenuators (74600-A, E, G, J, L, Q):	±0·05 db at any setting.
0 to 90 db Attenuators (74600-B, F, H, K, M, R):	±0·3 db at the 90 db setting falling linearly to ±0·06 db at the 10 db setting.

Performance at 50 Mc/s

0 to 0·9 db Attenuators (74600-C, S, T):	±0·015 db at the 0·9 db setting, falling linearly to ±0·006 db at the 0·1 db setting.
0 to 9 db Attenuators (74600-A, E, G, J, L, Q):	±0·15 db at the 9 db setting, falling linearly to ±0·05 db at the 1 db setting.
0 to 90 db Attenuators (74600-B, F, H, K, M, R):	±0·1 db per step.

Typical insertion loss figures for the 0 db setting at 50 Mc/s are:

0·1 db step attenuators:	0·07 db
1·0 db „ „ :	0·12 db
10 db „ „ :	0·12 db

IMPEDANCE

Representative figures for the return loss of the attenuators are given below (and also the corresponding reflection coefficients); they are *typical* figures at 50 and 100 Mc/s. The d.c. figures are better than these, being of the order of 40 db for return loss (0·01 for the reflection coefficient).

RL_i = return loss looking into the 0 db end of the attenuator with the far end correctly terminated.

RL_o = return loss looking into the maximum attenuation end with the 0 db end correctly terminated.

p_i and p_o are the corresponding reflection coefficients.

Attenuator	RLi(db)	RLo(db)	ρ_i	ρ_o	At
74600-A, G, Q	29 to 30	26 to 29	0·035 to 0·032	0·05 to 0·035	50 Mc/s.
„	22 to 25	23 to 26·5	0·079 to 0·056	0·071 to 0·047	100 Mc/s.
74600-B, H, R	30 to 32	30 to 31	0·032 to 0·025	0·032 to 0·028	50 Mc/s.
74600-C, T, S	30 to 32	30 to 32	0·032 to 0·025	0·032 to 0·025	„ „
74600-E, L, J	28 to 30	27·5 to 30	0·04 to 0·032	0·042 to 0·032	„ „
74600-F, M, K	29 to 30	30*	0·035 to 0·032	0·032*	„ „
„	—	21 to 23†	—	0·089 to 0·071†	„ „

* At the 0 db setting.

† At other settings.

PHASE SHIFT & GROUP DELAY

The phase shift for all models of the attenuator is almost directly proportional to frequency up to at least 50 Mc/s. This means that the group delay, for any setting of the attenuator, is virtually constant up to at least 50 Mc/s.

Typical figures for group delay are given below:—

	Group Delay in milli-microseconds			
	75Ω models		50Ω models	
Attenuator	At 0 db	Increment per step	At 0 db	Increment per step
0·1 db steps (0 to 0·9 db)	3·5	0·16	—	—
1·0 db steps (0 to 9 db)	3·5	0·4	5·1	0·28
10 db steps (0 to 90 db)	4·0	0·72	6·9	0·51

TEMPERATURE COEFFICIENT

The 0 to 9 db and the 0 to 90 db attenuators use cracked-carbon resistors having closely similar temperature coefficients of approximately −0·025% per °C. The mean of the insertion loss errors is very nearly zero, and the spread about the mean is very small, particularly if the terminating impedances are subjected to the same temperature variations and have the same temperature coefficient. A typical 74600-A Attenuator, for example, when set to 9 db, exhibited a change in insertion loss of 0·01 db with a change in temperature of 20°C.

A change of characteristic impedance will also occur with a change of temperature. This will be of the same order of magnitude as the temperature coefficient of the resistors, i.e. approximately −0·025% per °C.

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The 0 to 0·9 db attenuators exhibit insertion loss errors of approximately 0·00003 db per step per °C. At the 0·9 db setting, therefore, a 20°C. change of temperature produces an error of 0·0054 db approximately. The changes of characteristic impedance with temperature are negligible in these models.

MAXIMUM INPUT POWER

Based on resistor ratings, and assuming that the attenuators are correctly terminated, the maximum input powers are 10, 2·4 and 0·48 watts for the 0 to 0·9 db, 0 to 9 db, and 0 to 90 db attenuators respectively.

However, these maximum powers are considerably reduced when the attenuators are badly mismatched, and in any case it is desirable to work at as low a level as possible from the point of view of long-term stability.

CALIBRATIONS

Individual calibrations can be supplied by our Transmission Laboratories for all models if specifically requested. Unless the test frequency is specified by the customer, all models will be calibrated at d.c. and 50 Mc/s.

Using The Attenuator

SOME NOTES ON ACCURACY

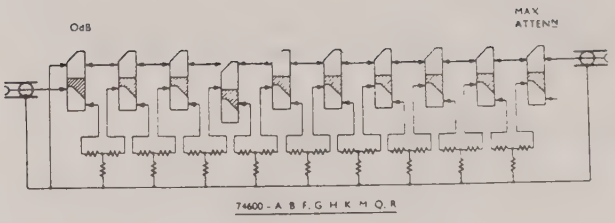
Insertion Loss

This is defined as the loss, expressed in decibels, caused by the insertion of a network into a transmission system.

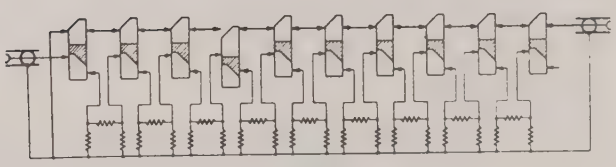
The use of an accurate attenuator does not necessarily ensure accuracy of insertion loss measurements. Particularly for measurements of high values of insertion loss, good screening of auxiliary apparatus and the use of well-screened connecting cables is essential. In addition, the accuracy depends upon the impedances of the test equipment and of the equipment under test.

Return Current

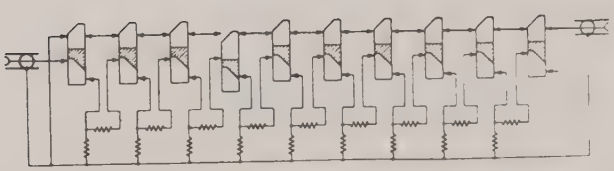
This is defined as a current wave reflected from a point of discontinuity in a transmission system, which may combine with the forward transmitted wave in such a manner as to cause irregularities in the steady-state characteristics of the system.



74600 - A B F G H K M Q R



74600 - E I L



74600 - C S T

DENOTES INSULATION ☐

SIMPLIFIED CIRCUIT DIAGRAMS

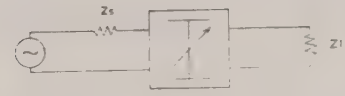


Figure 1

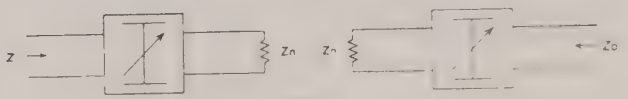


Figure 2

Return-Current Coefficient (or Reflection Coefficient)

This is defined as the vector ratio of the return current to the current that would exist at the point if the transmitting line or apparatus were extended under reflectionless conditions.

For apparatus of characteristic impedance Z terminated by an impedance W, the return-current coefficient is equal to $(W-Z)/(W+Z)$.

Return Loss

This is defined as the value of the coefficient of return current expressed in decibels. Quantitatively it is equal to $20 \log_{10}(W+Z)/(W-Z)$ decibels, in which $(W+Z)/(W-Z)$ is the reciprocal of the return-current coefficient.

An attenuator is generally used in a circuit as shown in Figure 1, where Z_s is the impedance of the source, and Z_l the impedance of the load. In practice, Z_s and Z_l will not be exactly equal to the nominal impedance of the circuit. Furthermore, the input and output impedances of the attenuator, Z_i and Z_o (see Figure 2), when the output and input respectively are terminated in the nominal impedance Z_n, are not in practice exactly equal to the nominal impedance of the attenuator.

The insertion loss, therefore, will not be exactly equal to the nominal value indicated by the setting of the attenuator. These errors, due to mismatching, are, of course, additional to the basic errors already quoted.

The normal formula used for calculating actual insertion loss is in terms of image or iterative parameters. For the practical evaluation of the small departures from the nominal insertion loss of attenuators, caused by variations in terminations, it is found to be more convenient to work with parameters which can be easily and accurately measured, i.e. the return losses or reflection coefficients against Z_n of the impedances (Z_i and Z_o) looking into each end of the attenuator with the other end terminated in Z_n.

Let ρ_s = reflection coefficient of Z_s against Z_n

ρ_l = „ „ „ Z_l „ Z_n

ρ_i = „ „ „ Z_i „ Z_n

ρ_o = „ „ „ Z_o „ Z_n

t = ratio of output to input currents when the network is terminated in Z_n. The nominal insertion loss can be shown to be $20 \log_{10} 1/t$ decibels.

Then it can be shown that:

$$\frac{\text{Nominal current ratio}}{\text{Actual current ratio}} = \frac{(1+\rho_s\rho_i)(1+\rho_o\rho_l)-(\rho_s\rho_l t^2)}{1-\rho_s\rho_l}$$

It will be seen that deviations from unity of the above ratio are caused by the *products* of errors, and each error itself is small. The extent of the deviations may be estimated for typical conditions:—

$$\text{Let } k = \frac{\text{nominal current ratio}}{\text{actual current ratio}}$$

(1) *Attenuator correctly terminated at both ends*

Here, $Z_s = Z_l = Z_n$ (nominal value of characteristic impedance)

$\therefore \rho_s = \rho_l = 0$

$\therefore k = 1$

no mismatch errors arise at any setting of the attenuator, irrespective of the reflection coefficients ρ_i and ρ_o of the attenuator.

(2) *Factory testing of the attenuators*

When the attenuators are tested at the factory, the terminations for the d.c. tests are such that ρ_s and ρ_l are not greater than 0·001, corresponding to a return loss of at least 60 db, and ρ_i and ρ_o are of the order of 0·01.

Hence, the maximum error due to mismatch in the d.c. tests is 0·0002 db.

For the H.F. tests, ρ_s and ρ_l are not greater than 0·01, corresponding to a return loss of 40 db. Taking $\rho_i = \rho_o = 0{\cdot}03$, the maximum possible errors due to mismatch in the H.F. tests are:—

0·0052 db at 0 db attenuation
0·006 db at 10 db „
0·0061 db at 20 db and higher attenuations

(3) *Using the attenuators with incorrect terminations*

When the attenuators are used for making measurements, both Z_s and Z_l will generally differ from Z_n.

Suppose both Z_s and Z_l differ by 10% from the nominal value.
Then $\rho_s = \rho_l = 0{\cdot}05$ approx.

Now, a typical figure for the return loss of the attenuators is 30 db, i.e. $\rho_i = \rho_o = 0{\cdot}03$ approx.

$k = 1{\cdot}0055 - 0{\cdot}0025\ t^2$ (in the worst possible case with the above values of ρ)

At 0 db attenuation, $t = 1$, $\therefore k = 1{\cdot}003$ and error = 0·026 db
„ 1 db „ , $t = 0{\cdot}8913$, $\therefore k = 1{\cdot}0035$ and error = 0·03 db
„ 10 db „ , $t = 0{\cdot}3162$, $\therefore k = 1{\cdot}00525$ and error = 0·045 db
„ 20 db „ , $t = 0{\cdot}1$, $\therefore k = 1{\cdot}00548$ and error = 0·047 db
„ 40 db „ , $t = 0{\cdot}01$, $\therefore k = 1{\cdot}00550$ and error = 0·048 db

In this case, therefore, even though Z_s and Z_l both differ from nominal by 10%, the worst error in insertion loss is 0·048 db (at 40 db and higher attenuations). In practice, ρ_i and ρ_o vary slightly with the loss setting of the attenuator, but not sufficiently to invalidate these results. When using a 0 to 0·9 db attenuator the variation over the range will be less than 0·008 db and when using a 0 to 9 db attenuator it will generally be less than 0·04 db. As attenuators are most often used for making relative measurements, the variation of the error over the loss range of the attenuator is of more importance than the absolute errors at particular settings.

It is evident from the above examples that a reflection coefficient of 0·03 for ρ_i and ρ_o (corresponding to a return loss of 30 db) is adequate to obtain reasonable accuracy.

The maximum errors likely to be obtained in practice with any terminations can be evaluated in a fairly simple manner. For this purpose, reference should be made to the typical figures for reflection coefficient given on page 3 under " Impedance."

Installation Data

The attenuators are designed for mounting on panels $\frac{9}{32}$ in. (7,1 mm) thick. With panels thinner than this, suitable distance pieces may be inserted under the mounting lugs.

The panel space occupied by the attenuators is $10\frac{3}{8} \times 2\frac{1}{2}$ in. (26,4 × 6,35 cm). The body of the attenuator projects behind the rear face of the panel to a depth of $3\frac{7}{8}$ in. (9,8 cm) for the 0 to 0·9 db and the 0 to 9 db attenuators (74600-C, S, T, A, E, G, J, L, Q), and to a depth of $4\frac{7}{8}$ in. (12,4cm) for the 0 to 90 db attenuators (74600-B, F, H, K, M, R). The coaxial connectors extend a further amount depending on the type of connector, and space must also be allowed for the input and output coaxial cords.

The drillings required for mounting the attenuators are shown in the diagram. Four holes to clear 2 B.A. screws are needed for fixing the attenuator to the panel. The ten push buttons are each $\frac{1}{2}$-in. (12,7 mm) diameter and project $\frac{3}{8}$-in. (9,5 mm) in front of the panel. Ten holes to clear these buttons are necessary, or alternatively a slot can be cut out of the panel to run the length of the row.

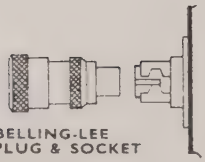
Two plugs (for attachment to the input and output cords) are supplied with each attenuator.

The weight of the attenuators is $3\frac{1}{2}$ lb (1,6 kg) for the 0 to 0·9 db and 0 to 9 db models, and $5\frac{3}{4}$ lb (2,6 kg) for the 0 to 90 db models.

Maintenance

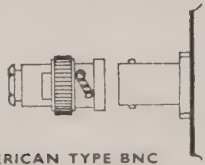
The H.F. and V.H.F. performance of the attenuators is dependent upon the precise positioning of the components and wiring, and no guarantee of their performance can be made if either the wiring or the components are disturbed. The switches are initially lubricated with a 10% solution of D.T.D. 825 grease in Esso Solvent No. 30 and should have a long life, as they have been type-tested for many thousands of operations.

Dimension	Inches	Millimetres
a	10·375	263,5
b	8 500	215,9
c	4 875	123,8
d	3 937	100,0
e	3·875	98,4
f	2·500	63,5
g	2·0	50,8
h	0·750	19,0
j	0·562	14,3
k	0 375	9,5
m	0·250	6,4
n	0·193	4,9



BELLING-LEE PLUG & SOCKET

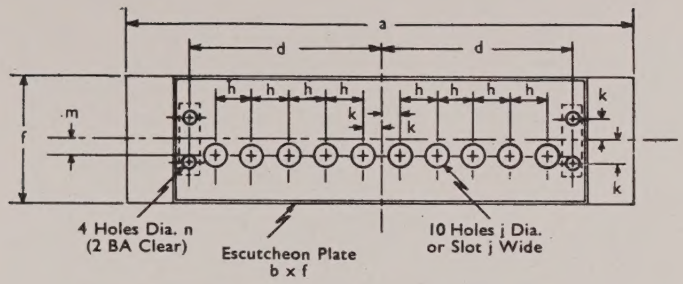
POST OFFICE PLUG & SOCKET



AMERICAN TYPE BNC PLUG & SOCKET
(Films & Equipment Ltd)

Grp.	Termination	Type of Case	Dimension x	Dimension y	Dimension z
A	Belling-Lee L734 Plug and Belling-Lee L604S Socket	I	0·500 in. 12,7 mm.	0·937 in. 23,8 mm.	7·312 in. 185,7 mm.
B	Belling-Lee L734 Plug and Belling-Lee L604S Socket	II	Flush	0·937 in. 23,8 mm.	7·812 in. 198,4 mm.
C	Belling-Lee L734 Plug and Belling-Lee L604S Socket	I	0·500 in. 12,7 mm.	0·937 in. 23,8 mm.	7·312 in. 185,7 mm.
E	Belling-Lee L734 Plug and Belling-Lee L604S Socket	I	0·500 in. 12,7 mm.	0·937 in. 23,8 mm.	7·312 in. 185,7 mm
F	Belling-Lee L734 Plug and Belling-Lee L604S Socket	II	Flush	0·937 in. 23,8 mm.	7 812 in. 198,4 mm.
G	Post Office No. 1 Plug and Socket	I	1·062 in. 27 mm.	1·125 in. 28,6 mm.	8 062 in. 204,8 mm
H	Post Office No. 1 Plug and Socket	II	0·562 in. 14,3 mm.	1·125 in. 28,6 mm.	8 562 in. 217,5 mm
J	Films & Equipt., Ltd. UG/88C/U Plug and UG 290/U Socket	I	0 750 in. 19 mm.	0·687 in. 17,5 mm.	7·312 in. 185,7 mm
K	Films & Equipt., Ltd. UG/88C/U Plug and UG/290/U Socket	II	0·250 in. 6,4 mm.	0 687 in. 17,5 mm.	7·812 in 198,4 mm
L	Post Office No. 1 Plug and Socket	I	1 062 in. 27 mm.	1·125 in. 28,6 mm.	8 062 in 204,8 mm
M	Post Office No. 1 Plug and Socket	II	0·562 in. 14,3 mm.	1·125 in. 28,6 mm.	8 562 in. 217,5 mm
Q	Films & Equipt., Ltd. UG/88C/U Plug and UG/290/U Socket	I	0·750 in. 19 mm.	0·687 in. 17,5 mm.	7·312 in 185,7 mm
R	Films & Equipt., Ltd. UG, 88C/U Plug and UG 290/U Socket	II	0 250 in. 6,4 mm.	0 687 in. 17,5 mm.	7·812 in. 198,4 mm
S	Films & Equipt., Ltd. UG 88C U Plug and UG·290 U Socket	I	0 750 in. 19 mm.	0 687 in. 17,5 mm.	7·312 in. 185,7 mm
T	Post Office No 1 Plug and Socket	I	1·062 in. 27 mm.	1·125 in. 28,6 mm.	8 062 in. 204,8 mm.

GENERAL DIMENSIONS OF THE ATTENUATORS AND MOUNTING PLATE DRILLING INFORMATION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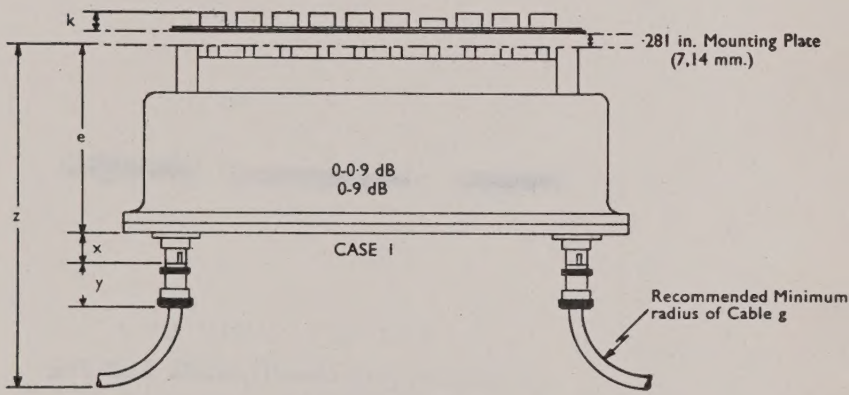
Escutcheon Plate
b x f
10 Holes j Dia.
or Slot j Wide


k
·281 in. Mounting Plate
(7,14 mm.)
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0-0·9 dB
0-9 dB
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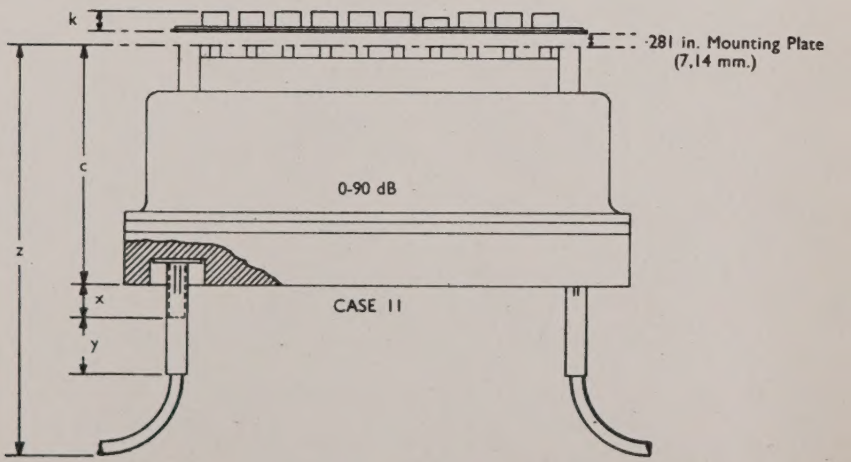
y
CASE I
Recommended Minimum
radius of Cable g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(7,14 mm.)
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CASE II

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